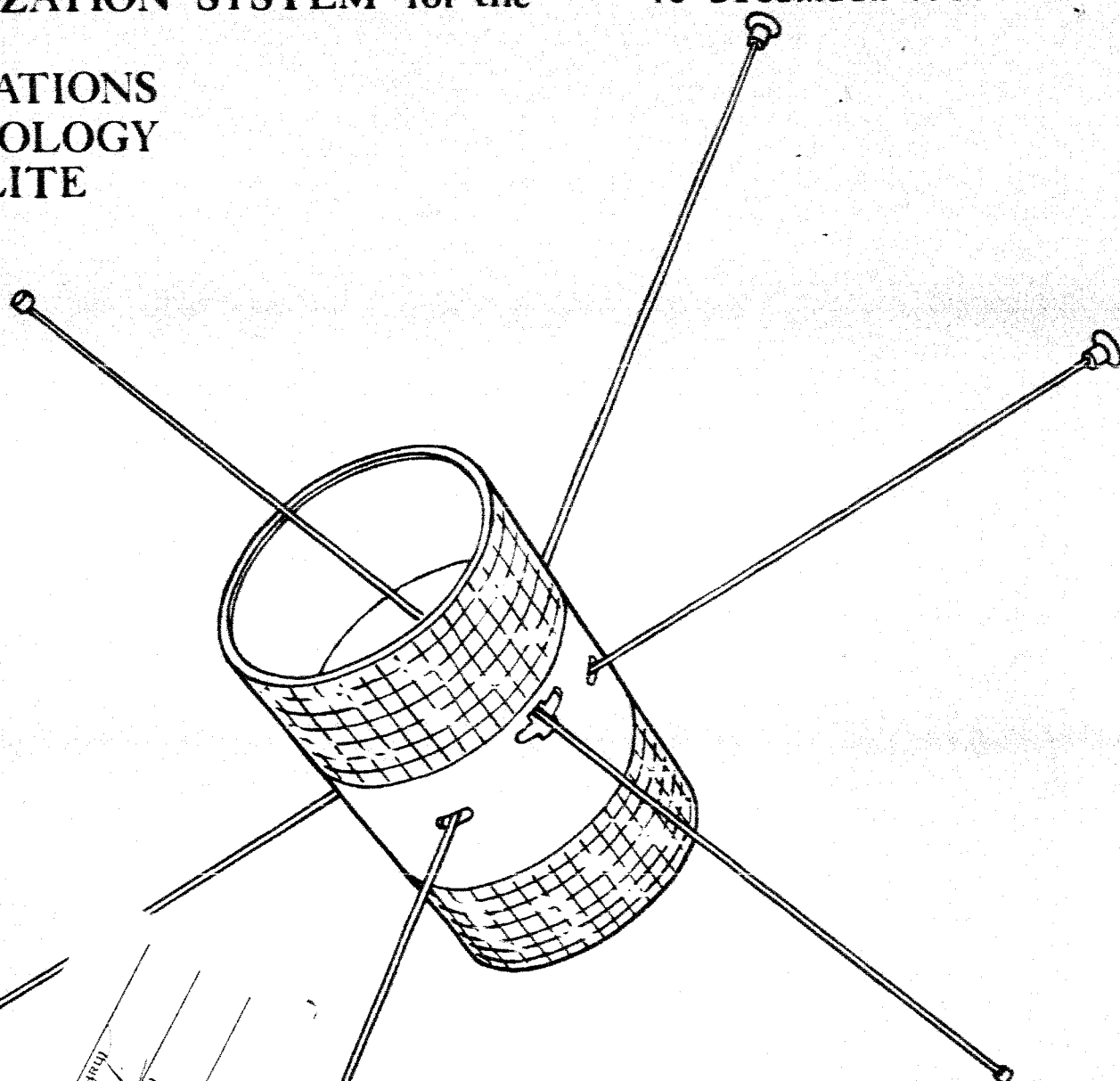


GRAVITY GRADIENT STABILIZATION SYSTEM for the

DOCUMENT NO. 65SD4515
10 DECEMBER 1965

APPLICATIONS
TECHNOLOGY
SATELLITE



SEVENTEENTH MONTHLY PROGRESS REPORT

NASA CONTRACT NAS 5-9042

GENERAL  ELECTRIC
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GRAVITY GRADIENT STABILIZATION SYSTEM
FOR THE
SEVENTEENTH MONTHLY PROGRESS REPORT

1 NOVEMBER THROUGH 30 NOVEMBER 1965

CONTRACT NO. NAS 5-9042

FOR THE
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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SECTION 1

INTRODUCTION

1.1 PURPOSE

This report documents the progress during the seventeenth month of design and fabrication efforts for the Gravity Gradient Stabilization System of the Applications Technology Satellite. The report covers the period from 1 November through 30 November, 1965.

1.2 SCOPE

Under Contract NAS 5-9042, the Spacecraft Department of the General Electric Company has contracted to provide Gravity Gradient Stabilization Systems for three Applications Technology Satellites: one to be orbited at 6000 nautical miles and two which will be orbited at synchronous altitude. The gravity gradient stabilization system will consist of primary booms, damper, attitude sensors, and a power control unit. Two sets of aerospace ground equipment will also be furnished to enable ground checkout of the gravity gradient stabilization systems.

SECTION 2

SYSTEMS ANALYSIS AND INTEGRATION

2.1 ATS MATHEMATICAL MODEL

The new DERIV module has been written in engineering terms and programmed. Checkout of the basic program (straight rods) is in progress and should be complete by the end of December. The largest portion of the basic program is the new DERIV module.

New solar torque/thermal bending modules have been written in engineering terms and are being programmed. Programming should be complete by the end of December.

Revised schedule for completion of the Mathematical Model calls for a 15 April 1966 delivery date.

2.2 ATTITUDE DETERMINATION PROGRAM

With the use of the Attitude Determination Investigation Program (ADP) and the Error Analysis Program a study is progressing in the sensitivity of sun and earth direction cosines to simulated spacecraft attitude. From this study contour maps will be generated of constant sensitivity for an orbit simulation of approximately one year. This study has been slowed somewhat by late changes in sun sensor locations and orientations on the spacecraft. A special sensitivity coefficients tables routine has been inserted in the Error Analysis Program for this study.

An investigation of attitude determination during a controlled pitch maneuver was performed and a simplified mathematical technique was formulated for inclusion as a subroutine in the ADP. This routine assumes, during such a maneuver, earth direction is lost and antenna polarization data deteriorates. Thus, sun sensor data and the known pitch angle in the orbital frame are the determinators of spacecraft attitude. For various combinations of inputted roll and yaw error up to 5 degrees and a pitch maneuver from 0 to 90 degrees,

the worst case pitch error generated was approximately 1 degree. (See PIR 4424-055, Attitude Determination During a Pitch Maneuver," by T.F. Green, 1 November 1965.)

In response to an action item to determine the accuracy expected from attitude rate calculations in the ADP, an investigation was performed in which it was assumed that a "least squares filter" is a good approximation of the differentiation process in determining attitude rate. From this it develops that the determination of attitude rates is a function of the attitude frequency. A response curve for this simple model is included in PIR 4424-056, "Remarks on Calculation of Rates and Farady Rotation." Also discussed in this PIR was the conclusion reached on the effects of Faraday rotation corrections to polarization data. It is concluded at this time that this correction should not be performed for the following reasons:

- a. The Farady rotations expected for ATS-A would be on the order of 2 degrees or less which is less than the quoted accuracy (from NASA/GSFC) of the polarization angle measurement.
- b. The effect of Faraday rotation is approximately inversely proportional to the square of the radio frequency and therefore for ATS-A Faraday correction should be less than the 2 degrees experienced by D. L. Mott in his analysis for Syncom II, 1963.
- c. The daily variations in spatial electron density and the earth's magnetic field are not fully known and must be estimated for inclusion in the Farady rotation calculation.

System specification SVS-7429 was published to describe the data formats of all telemetry data transmitted between NASA and GE. This document has been submitted to NASA for approval. The data format descriptions included are:

- a. GE Raw Telemetry Data Tape (RTDT)
- b. NASA Attitude Data Tape (NADT)
- c. TV 35mm film
- d. Quick Look TTY data to and from GE.

The NASA Goddard Orbit Model computer program was received by NASA and converted from Fortran II to Fortran IV. A conversion problem has been experienced and a working meeting at Goddard with R. Chaplick has been tentatively scheduled for 9 December to resolve this problem.

2.3 ORBIT TEST PLAN

Documentation of current gravity-gradient orbit test philosophy has been completed and issued as ATS Systems Memo No. 068. Included in the memo is a tentative sequence of orbital tests and within each test, a tentative sequence of test events. The complete Orbit Test Plan, in preparation, will include the chronology of operations and commands, test constraints and contingencies, data requirements, and data evaluation techniques. Documentation of the Orbit Test Plan will follow a "package" format; each package will be a self-contained description of a single-purpose gravity-gradient orbital test. With some exceptions, the sequencing of these packaged tests is dependent upon a final evaluation of the success probability (and the consequences of a test failure) associated with each test. Time sequencing, within each package, will be based on an arbitrary start time for the individual test. This will be done to provide sufficient flexibility for the following:

- a. Operational resequencing of test packages may be required. Some tests, such as "thermal twang" evaluation, require specific orbital conditions at the time of test initiation to ensure significance of resultant test data. The specific time for initiation of such tests cannot be established (in other than gross terms) until the ATS orbit has been achieved and its specific characteristics known.

- b. Operational repetition of tests may be required. Pitch inversion, for example, may involve certain "trial and error" characteristics and the success of a given inversion attempt must be established before proceeding to the next test in the planned sequence. Other tests may require a period of post-test data evaluation before proceeding to the next test.
- c. Critical, short term experiments may require that the sensor system be operating at peak efficiency (maximum accuracy) at a given time in the test. This requires the simultaneous satisfaction of constraints due to orbit geometry, time of day, ground station coverage, etc., and is best done at a time near to test initiation so that predictions of these effects can be performed with reasonable accuracy and test initiation time can be designated accordingly.

2.4 FLIGHT EVALUATION PLAN

Flight evaluation planning efforts have been directed toward establishing details of the weekly analysis operation for ATS/A, D, and E, as outlined below:

I. Attitude Determination

- Input data quality
 - data accuracies
 - data continuity
 - data redundancies
- ADP operation
 - intermediate outputs
 - confidence check indications
- Output data quality
 - accuracy
 - continuity

II. Performance (vehicle attitude)

- ADP output data
- Math model data

- Gravity gradient configuration
- Orbit characteristics

III. Diagnostic (System hardware)

- X-boom subsystem
- Damper subsystem
- PCU
- Sensors
 - Solar Aspect Sensor
 - Television system
 - Damper instrumentation
 - Earth sensor (for use in evaluating attitude data quality)

In each phase of activity, detailed formats to be used in data presentation are being specified. Weekly data will be scanned by computer on a file-by-file (i. e., station pass) basis, and summarized results will be presented in one of several "survey" formats. This summary will give initial status (system and subsystem operating configuration) of the vehicle at acquisition, and indicate any subsequent change in this status during the contact period. Diagnostic functions (temperatures, voltages, etc.) will be surveyed and summarized, with any out-of-limit function being noted.

Complementing these survey formats will be detailed subsystem formats, available for more comprehensive presentation of data pertinent to a particular system or subsystem. These formats will be available on an as-requested basis.

2.5 BOOM THERMAL BENDING TEST PLAN

Plans for ATS boom thermal bending tests were finalized during November; GE/NASA working sessions led to an agreement to utilize the existing NASA test facility for a series of jointly conducted tests by GE and NASA personnel. The tests, plus analysis, are

considered by GE to be essential to the specification of realistic values for the magnitudes of the constant coefficients utilized in the thermal bending subroutine of the ATS Math Model. The Math Model equations (Fourth Quarterly Progress Report) are incorporated empirically with values for the empirical constants required as inputs to the Math Model program. This allows maximum flexibility in the manipulation of the thermal bending analytical model without necessitating changes in the ATS Math Model. As knowledge of the thermal bending phenomena increases, the ATS Math Model can be "updated" by the simple expedient of adjusting the program input values for the empirical constants.

The initial test to be performed will utilize a seamless stainless steel (type 304) "control" rod, 1/2-inch diameter with a 0.020-inch wall thickness. Later tests will utilize bare beryllium-copper rods with the overlap geometry and wall thickness (0.002 inch) of the ATS configuration. All rods will be approximately 3 feet in length and instrumented, by GE, with approximately 20 thermocouples each. Test objectives include the measurement of temperatures to $\pm 0.3^{\circ}\text{F}$ and deflections, along the rod, to an accuracy of ± 0.001 inch. Identically prepared, uninstrumented rods will be available as a back-up in the event that test results with the instrumented rods cast doubt on the current assumption that the thermocouple instrumentation will not affect the deflection response of the rods.

The objective of the "control" rod test is, in essence, to evaluate the basic experimental technique to be used for the ATS-type rods. Theory for seamless tubes is well-developed and rigorous; hence, correlation between test and theory should be excellent if the basic experimental approach is valid. The thermal conductivity of a 0.020-inch wall stainless steel tube is approximately the same as for a 0.002-inch wall beryllium-copper rod. Hence, the temperature gradients should be approximately the same for both types of tests. The beryllium-copper rods will not be silver-plated since the consequent reduction in thermal absorptivity would reduce the temperature gradients below that for which the instrumentation accuracy is considered acceptable.

2.6 BOOM THERMAL BENDING ANALYSIS

Documentation and checkout of the gravity-gradient rod shell analysis has been initiated and will result in a unified final report entitled "Gravity Gradient Rod Stiffness Matrix Analysis." The mechanics of operation of the associated digital computer program will be included. The resultant program, in conjunction with results from the thermal bending tests of Section 2.5, will be used to generate data essential to the specification of the empirical constants in the thermal bending subroutine of the ATS Mathematical Model.

2.7 BOOM DYNAMICS ANALYSIS

Setup of the boom dynamic equations, as described in the Fifth Quarterly Progress Report, has proceeded toward completion. Computations will utilize a GE -proprietary computer program designed for general equations were formulated for computation. Development of the coordinate transformation coefficients consumed over 250 computational operations (multiplications and additions). Approximately 600 additional operations are required for the remainder of the left side of the equation. The present computational system is capable of only 500 operations exclusive of integrations. As a result of this limitation the first computation is being reduced to allow rotation about a single axis in order to obtain a preliminary evaluation of the dynamic effects. As soon as this computation is debugged, effort will be expended to reincorporate the full set of equations by economizing on operations, use of table look-ups, stepwise linearization or a combination of all three.

2.8 SYSTEM DESIGN ANALYSIS

2.8.1 ATS PITCH INVERSION STUDIES

An analysis is being performed to determine the following:

- a. Nominal timing sequence for inversion thrusters.
- b. Thrust level tolerances of inversion thrusters.
- c. Effects of disturbances upon the thrust level tolerances.

A. ATS-A.

Nominal timing sequences have been established for a range of values of η , the multiple of total energy required to invert the vehicle. The effects of η upon thrust level tolerances have been determined. The final choice of η has not been made. This value will be a compromise between minimizing η to conserve propellant, and choosing a value of η at which the allowable thrust level tolerances are maximum. This choice cannot be made on the basis of this study alone. For instance, if the allowable thrust level tolerances are far below the values that can be achieved, it may be necessary to abandon the concept of inversion based on time only. In this event it may be best to choose η to minimize propellant consumption.

The first two items listed above have been completed. Under the third item the effects of thruster misalignment, short primary gravity-gradient rods, and solar and magnetic effects on thrust level tolerances have been determined. The effects of initial conditions, with and without orbit eccentricity, on thrust level tolerances are presently under study.

B. ATS-D

The initial analysis and computer runs required to determine nominal timing sequences have been completed. However, these runs are based on the torque levels associated with a 29-inch thruster moment arm. The effect of relocating the thrusters such that the moment arm is reduced from 29 to 7 inches (HAC's System Summary document dated 1 October 1965) must now be investigated. This will require a complete rerun at the reduced torque levels and will obviously result in an inefficient utilization of the inversion system capability.

2.8.2 PERFORMANCE ERROR STUDIES

Table 2-1 outlines the progress made to date on the error studies for both ATS-A and ATS-D/E. Each error source has been considered independently of others and has been, in most cases, evaluated over an arbitrary range. Most of the results have been

documented as PIR's. When all error studies have been completed, a final "best estimate" of nominal system performance will be provided and a summary report issued.

TABLE 2-1. ERROR STUDIES PROGRESS SUMMARY

ERROR SOURCE	ATS-A	ATS-D/E
Solar Torques		
Unequal absorptivities with damper booms without damper booms	In process complete	In process complete
Rod bending TV targets	Preliminary plots done in process	In process complete
Rods		
Envelope and mounting errors	Complete	Complete
Individual rods short	To be done	In process
Spring null shift	Complete	Complete
Angle-damper/main	Complete	Complete
Mount cocking	Complete	Complete
Rod degradation	Complete	Complete
Thruster	N. A.	In process
Magnetic Dipole	Complete	Complete
Internal Rotating Machine	Complete	Complete

SECTION 3

BOOM SUBSYSTEM

3.1 KEY EVENTS

The key events which took place during November include:

1 November 1965	Engineering Unit T-1a primary boom qualification level sinusoidal and random vibration tests begun.
3 November 1965	Post vibration performance tests started on T-1a primary boom.
5 November 1965	Disassembly and inspection of T-1a primary boom started.
23 November 1965	Detail drawings for primary boom problem resolution received from deHavilland.
29 November 1965	Sample BeCu bellows electron beam welded at GE.

3.2 DAMPER BOOM RELEASE MECHANISMS

DeHavilland has conducted two bench tests on the Avdel ball-lock release mechanism, Horex thruster and associated mechanical means for damper boom release. The adequacy of the boom release scheme for accomplishing its intended purpose was proven in these bench tests.

3.3 ENGINEERING UNIT - T-1a PRIMARY BOOM ASSEMBLY

Sinusoidal and random vibration to qualification levels was conducted with plugs placed in the TV target standoffs to restrain the end caps from moving during vibration and unlatching the tip masses, as was experienced during the initial resonance search phase.

Vibration of T-1a was conducted in the Y-Y, Z-Z and X-X axes in the following sequence:

- a. 1g resonance search
one-half qualification sinusoidal run
- b. 1g resonance search
full qualification sinusoidal run
- c. 1g resonance search
full qualification random run
- d. 1g resonance search

Performance testing after vibration in the Y-Y axis was limited to tip weight uncaging which was satisfactory. Performance testing after vibration in the Z-Z axis was limited to tip weight uncaging and partial deployment (about 3 feet). Both operations were satisfactory; however, an inspection revealed several cracks at two separate locations on each boom (at attachment to end cap and at drum support rollers). Performance testing after vibration in the X-X axis was limited to uncaging, partial deployments (about 3 feet and 56 feet), normal and standby scissoring. All operations were satisfactory; however, inspection of both booms during the 3-foot deployment revealed that Boom 2 was cracked again at the drum support rollers while Boom 1 sustained only wrinkles. Both booms showed evidence of cracking at the attachment to the end cap.

The other partial deployment with Boom 2 on the test track trolley and Boom 1 in the take-up mechanism resulted in a dramatic Boom 2 element failure. At a deployed length of 56 feet, the trolley stopped its forward motion. When power was removed from the unit, inspection revealed that the element had split from both edges diagonally toward the center at the entrance to the guide within the erection unit and had reverse wound on the storage drum. Inspection after removal of Erection Unit 2 from the assembly revealed that the storage drum support bearings had hung up in the kidney-shaped guide slots. Resulting damage to the element is shown in Figure 3-1.

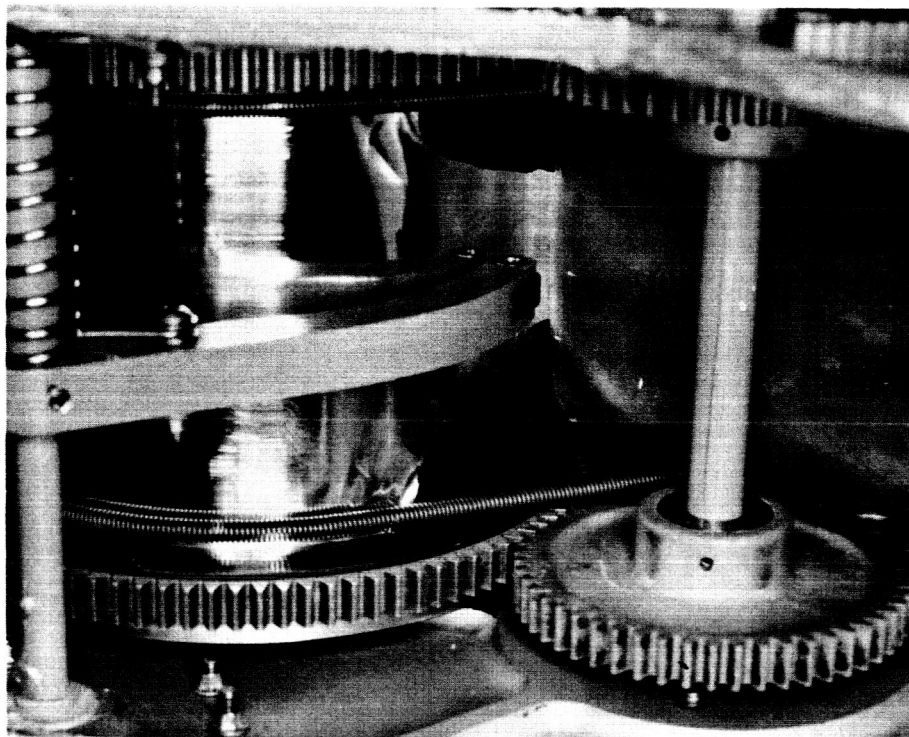


Figure 3-1. Erection Unit 2 Boom Element Failure, T-1a Primary Boom Package

In an effort to determine whether the boom element failure was due to bearing hang up or element edge defects, the boom in Erection Unit 1 was manually deployed on the test track and reverse winding again occurred but without element tearing. Observations during manual deployment indicated no edge defects at the time of repetition of the reverse winding failure. Subsequent removal of this erection unit revealed that the storage drum support bearings had hung up in the kidney-shaped guide slots. Result of the damage to the element in Erection Unit 1 are shown in Figure 3-2.

Concurrence on resolution of the four problem areas uncovered on the primary boom during vibration resulted in submittal of detail drawings by deHavilland for rework of T-1a parts to incorporate the fixes for further vibration testing. A retrofit kit of all new parts will be supplied by deHavilland and the T-1a existing parts will be reworked by GE. The four distinct problems involved are:

- a. Tip weight uncaging.
- b. Element cracking at drum support rollers.
- c. Bearing hang up in kidney slot.
- d. Element cracking at end cap attachment.

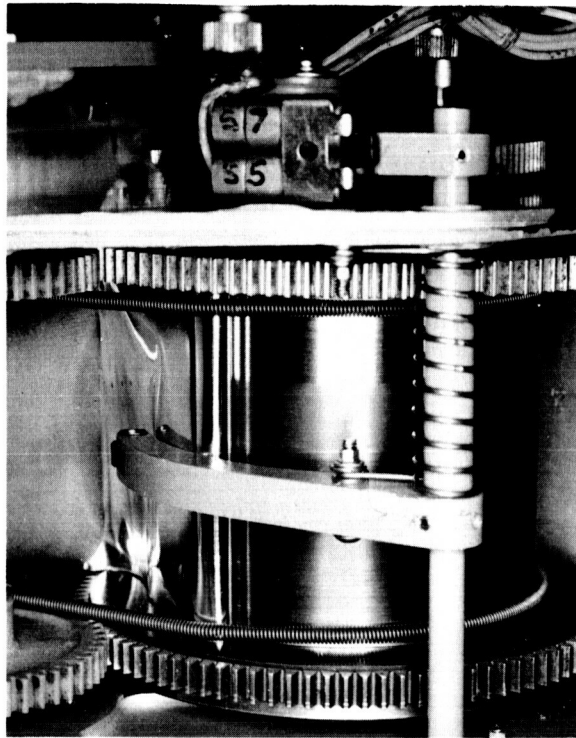


Figure 3-2. Erection Unit 1 Boom Element Failure When Manually Deployed, T-1a Primary Boom Package

Tip weight uncaging resulted from "stacking" of the element on the drum during vibration. Essentially the element became more tightly wound on the drum and this tightening resulted in enough movement of the end cap so that the caging springs were disengaged from the locking grooves within the tip weights, thus releasing the tip masses. See Figure 3-3. The basic problem is that tip weight uncaging is directly dependent upon boom element movement. The fix will incorporate a flexible latching cable which ensures that tip weight uncaging is independent of element movement due to "stacking". The flexible cable will be inserted into the unit through the end of the tip weight and guided to a special worm gear attached to the internal polycarbafil drum drive gear. Engagement will be accomplished by screwing the cable into engagement with the special gear and locking in place. Disengagement will occur only with rotation of the drum drive gear.

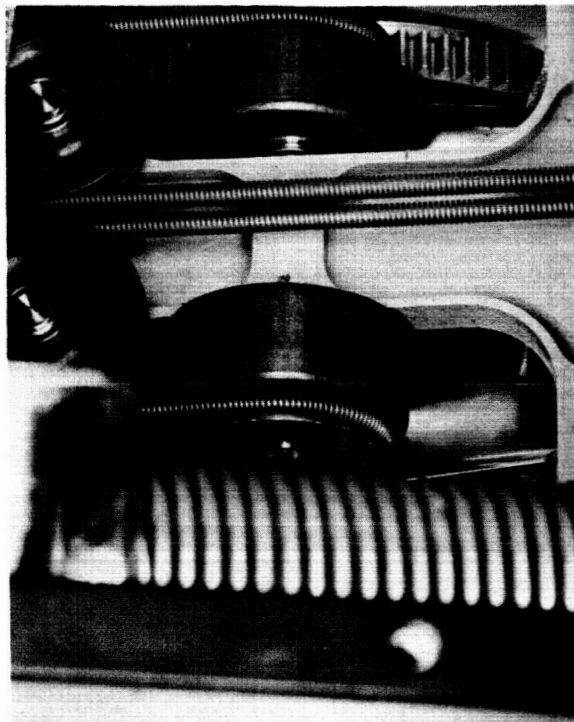


Figure 3-3. Crease in Guide of Erection Unit Before Disassembly, Primary Boom Package T-1a

Element cracking at the drum support rollers was a direct result of insufficient element stored on the drums. The original design specified 150-foot booms and the kidney slots were designed for this capacity. However, the length was subsequently changed to 132 feet. The fix to compensate for the difference in design capability and actual capability will be to incorporate a kidney guide slot "snubber". This snubber will fill up the kidney slot to reduce the effective drum-support bearing movement to that anticipated at 150-foot capability.

Bearing hang up in the kidney slot resulted from inadequate kidney slot bearing surface for the drum-support bearings. The fix for this inadequacy will be the incorporation of a hardened bearing support housing around the bearings. This housing will do the bearing guide within the kidney slot and provide a larger, more adequate bearing surface to react axial loads.

Element cracking at the attachment to the end cap is a direct result of the method of attachment. The present semi-cylindrical mounting plate forces the element to assume its circular

shape faster than it would under natural circumstances. This unnatural restraint results in excessive "scissoring" of the element edges at the point of attachment. The fix would incorporate a flat mounting plate to allow element to assume the circular shape at a more natural rate thereby reducing the scissoring and resultant cracking.

When vibration testing is resumed, the four fixes will be installed in only one of the units. The other erection unit in the assembly will have no fixes installed. This procedure will help identify the axis of failure which also provide a basis for comparison of the adequacy of the fixes. Complete performance tests will be conducted after vibration in each axis.

The T-1b bellows assemblies, which were electron-beam welded by GE for deHavilland, were found to leak under test. The trouble appeared to be poor fit of piece parts which resulted in porous welds. The fix defined for T-1b is epoxy sealing to hold pressure. Test for structural adequacy of bellows and weld will not be affected. Prototype welds will require re-configuration.

SECTION 4

COMBINATION PASSIVE DAMPER

4.1 SUMMARY

Major events that have occurred during November include:

- 5 November - The CPD thermal unit was returned to GE from HAC since vehicle thermal tests have been deleted and no need for the CPD thermal unit existed at HAC. This unit will be used on the systems mockup at GE.**
- 18 November - CPD alignment problems discussed at GE at a meeting with NASA representatives.**
- 22 November - The CPD Engineering Unit was delivered to the test area from final assembly. The assembly and checkout of the "live" CPD proved much more difficult than anticipated; however, much valuable "learning" information was obtained which can be profitably applied to future CPD assemblies.**
- 22 November - Electrical checkouts and first pyrotechnic firing to uncage were successfully completed on the CPD.**
- 30 November - Functional testing of the CPD on the LOFF and ADTF is proceeding on schedule.**

4.2 DESIGN DEVELOPMENT EFFORTS

4.2.1 CONFIGURATION STATUS

Assembly of the CPD Engineering Unit 1 was completed on Sunday, 21 November, and engineering evaluation tests were begun the following day. Hi-pot electrical tests were successfully completed. The uncaging squibs were fired separately, and the cable cutters performed as required.

The eddy-current damping factor was found to be 18% below the nominal value. However, this value is not excessive because there is a 15% tolerances on the nominal value, and the magnets can be charged to a higher value to meet the required damping factor.

Performance of the damper boom angle indicator was tested and found to be repeatable. Accuracy of the angle indicator will be evaluated in later tests.

4.2.2 ENGINEERING UNIT 1

Assembly of the CPD Engineering Unit 1 was completed on 21 November, and the unit was immediately moved to the laboratory for engineering evaluation testing. Because this unit was the first assembly of a functional CPD package, a number of problem areas were uncovered in planning, assembly fixturing and parts utilization, especially fasteners. These difficulties were expected as a part of the normal "learning" curve and they were recorded as they occurred and will be evaluated to determine what changes will be required to drawings and planning to simplify the assembly of Engineering Unit 2. Problems associated with installation of wiring harnesses will be lessened for Engineering Unit 2 since a mockup of the CPD will be used as a model for fabricating the harnesses before they are installed in the second engineering unit.

Engineering evaluation was begun on 22 November in accordance with the "Engineering Test Plan for CPD" which was published in PIR 4176-085 (Revision A), dated 27 July 1965. Functional tests are scheduled to be performed on the Low Order Force Fixture (LOFF), and the Advanced Damping Test Fixture (ADTF), as appropriate. Dipole testing will be

conducted in the applicable environmental test area. All test facilities are located in the GE Space Technology Complex at Valley Forge, Pennsylvania. The test series will include:

- a. Functional tests
- b. Vibration
- c. Acceleration
- d. Solar vacuum
- e. Thermal
- f. Humidity
- g. Thermal functional

Requirements for the above environments are in accordance with the provisions of the Combination Passive Damper Specification, SVS-7314.

Electrical checkout was successfully completed and the uncaging cable cutters were fired preparatory to going on the ADTF for damping tests. Cable cutter performance, and the associated uncaging mechanism, was perfect. Results are shown in Figure 4-1.

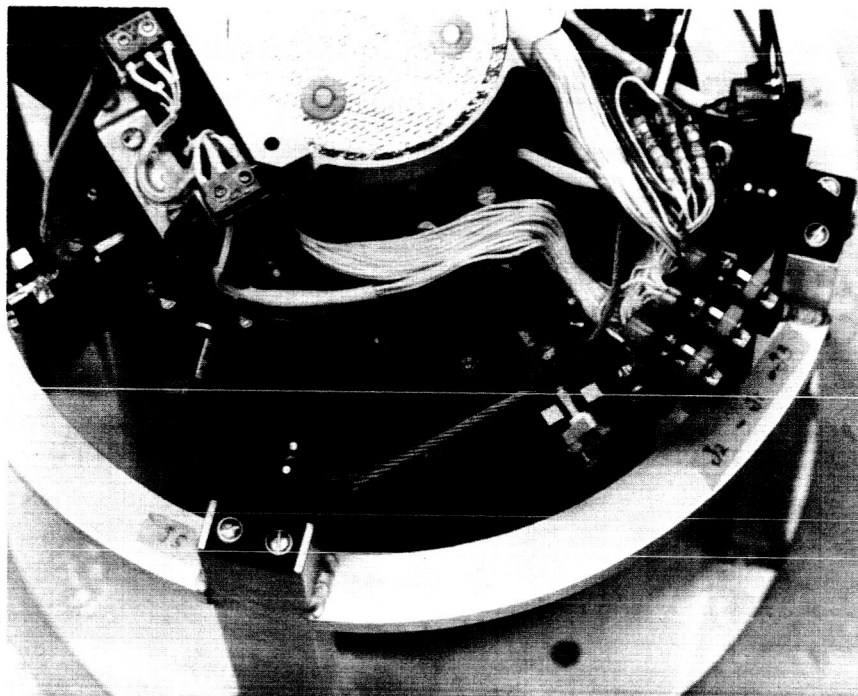


Figure 4-1. Cable Cutter Performance, Engineering Unit 1

The cable ends were well restrained within the baseplate after the cable cutter squibs were fired; no damage was done to the thermal shield or to any harness runs in the vicinity of the cables. The accompanying shock to the CPD was estimated to be minimal since the noise accompanying the decaying operation was very slight. Both of the redundant decaying squibs were fired in sequence (not concurrently). It was noted that the cutter which was actuated after the tension in the cable had been released (i. e. , the first cutter had cut the cable and uncaged the dampers, completely severed the slack cable.

4.2.3 EDDY-CURRENT DAMPER

Alterations were made to most of the eddy-current damper drawings, including alterations to the torsional restraint and diamagnetic suspensions, as a result of experience gained during the fabrication of parts for an assembly of Engineering Unit 1. Tolerances have been relaxed wherever possible to aid in assembly of the second engineering unit and the prototype hardware.

The flux density of the eddy-current damping magnets was measured after they were installed in Engineering Unit 1, and the results were exactly as measured during the in-process tests which had been conducted previously. The low damping factor, noted in eddy-current damping test conducted after, was attributed to the low conductivity aluminum rather than by magnet changes. The in-process tests were conducted using another damping disc than the one in Engineering Unit 1 since this disc was not available at the time of the in-process testing.

An analysis of damping torque observed in Engineering Unit 1 and the level of charge given to the magnets during in-process adjustment shows that the eddy-current damping torque can be adjusted to be well within specifications by increasing the charge in the magnets toward the saturation point.

Radial Force Tests were run on the suspension system of the eddy-current damper. Measurements in two directions (with and against the torsional restraint system) showed that the suspension forces obtained were very close to the design predictions (which are in themselves conservative):

<u>Direction</u>	<u>Measured</u>	<u>Predicted</u>
Fx	7.93 dynes/0.001"	6.2 dynes/0.001"
Fy	13.6 dynes/0.001"	13.0 dynes/0.001"

Tests were made on a laboratory set-up of the torsional-restraint system to determine if the proximity of the eddy-current damper magnets had any effect on the performance of the torsional restraint system. No measurable effect was observed with either the ATS-A or ATS-D/E torsional restraint configurations.

As reported in the Sixteenth Monthly Progress Report, the torsional restraint pattern material used in the eddy-current damper was changed to carbonyl iron-epoxy to satisfy minimum hysteresis requirements. Test samples of specimens having 5% and 10% carbonyl iron have been evaluated. It has been determined that the method by which the constituent materials are mixed is extremely critical to obtaining satisfactory linearity. Techniques have now been identified, repeatably produced, tested, and found to have acceptable linearity.

4.2.4 ANGLE INDICATOR

A parallel approach was taken toward obtaining a satisfactory encoder disc master. GE and the vendor are both making a pattern master. This approach was undertaken because the vendor has not been able to produce a useable even master through the requirements are within the state-of-the-art. In addition, GE will make a minimum and maximum feature master which will be used for inspection.

Continuing tests on the fiber optic assemblies indicate that the randomizing process developed by the vendor results in more uniform light distribution.

Test of fiber optics serial No. 7 and 8 show approximately 8 to 10% variation between maximum and minimum output using all readings from both filaments.

Tests of the angle indicator elements installed in CPD Engineering Unit 1 show the switching points of the various bits to be extremely repeatable. No evaluation of component accuracy

can be made in this unit because the encoder disc used was known to be inaccurate, but a more accurate one was not available for this assembly. A test fixture has been designed which will permit an exact measurement of the indicator accuracy before assembly into the CPD, but the vendor selected to fabricate this fixture has not been able to satisfactorily complete the unit to date. Efforts continue to be made to obtain this test fixture.

4.2.5 HANDLING FIXTURE

The CPD handling fixture was fabricated and test-fitted to the CPD during November. It is shown mounted on the CPD dynamic model in Figure 4-2. The fixture was designed so that the CPD can be handled readily to facilitate mounting into the ATS spacecraft without damage to the CPD or the associated damper booms.



Figure 4-2. Demonstration of CPD Handling Fixture

4.3 PASSIVE HYSTERESIS DAMPER

Revision C of the source control drawing for the hysteresis damper (GE Dwg. 47D207083) was released during the month. This revision incorporates all outstanding AN's (Alternation Notices) which had been issued against the drawing.

GE Quality Control has approved (by TWX) all Qualification plans and other procedures submitted by TRW, Inc.

TRW, Inc. completed the first portion of the ATS-D/E wire qualification test. The wire passed four qualification vibration tests in thrust axis, while installed in the hysteresis damper development model. It then passed 140,000 torsional oscillations at ± 60 degrees with no apparent degradation. In the later test of Wire No. 2 (0.003 inch diameter) the wire broke during a second quality run. TRW, Inc. is investigating the failure.

4.4 TEST EQUIPMENT

All mechanical test equipment, cable and console wiring drawings for the CPD were completed. Electrical checkouts of Console 1 and 2 were completed.

A series of setups was completed on the LOFF and ADTF equipment using the dynamic model of the CPD as a mockup of the completed CPD. These exercises gave the test personnel an opportunity to verify test procedures and to assure availability of all necessary parts in advance of engineering testing using Engineering Unit 1. The setup measuring radial force is shown in Figure 4-3. The axial force setup is shown in Figure 4-4. The overturning torque test setup is shown in Figure 4-5.

Air bearing manometer accumulators, were designed to protect the air bearing from possible water damage in the event of a large bearing pressure differential and the resultant manometer blowover. These units were fabricated and installed on all air bearings.

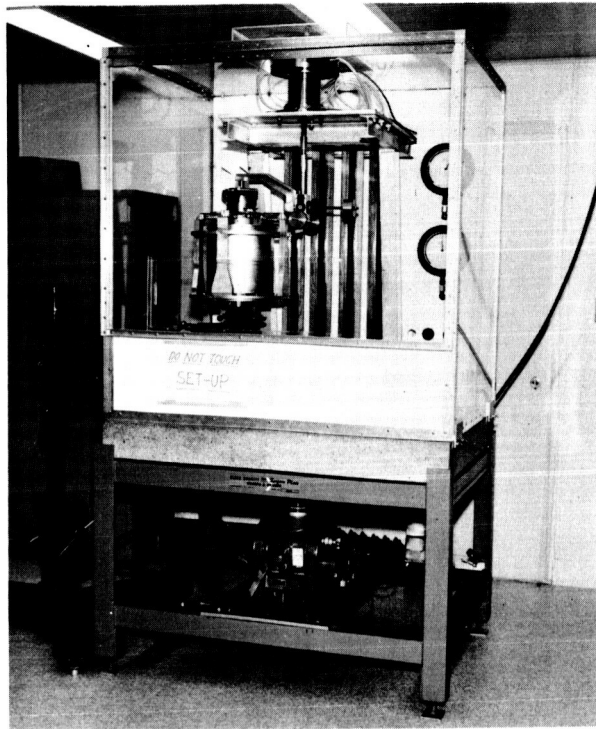


Figure 4-3. Radial Force Measurement Test Setup on LOFF

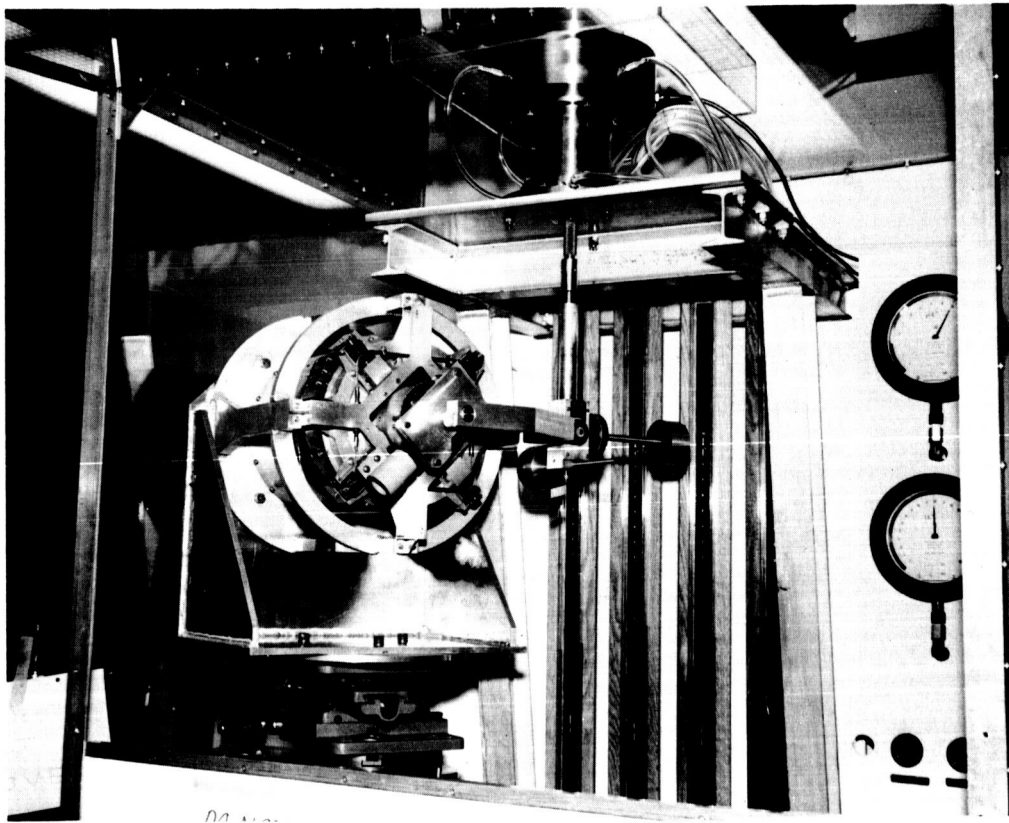


Figure 4-4. Axial Force Measurement Test Setup on LOFF

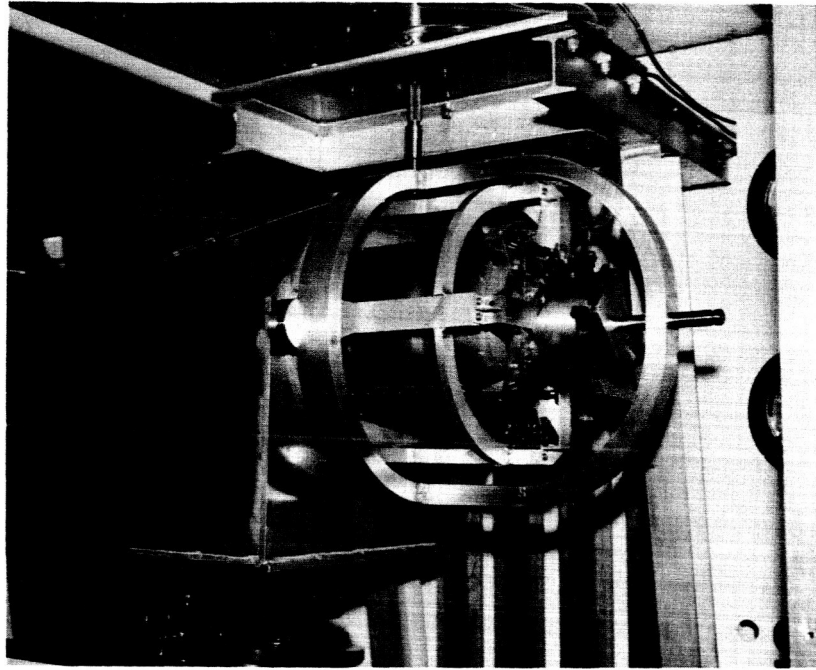


Figure 4-5. Overturning Torque Test Setup on LOFF

The CPD test console was checked-out. A close-up view of the console panels is shown in Figure 4-6. The top panel controls the functions of the angle indicator (detector). The lower panel contains the controls for the CPD functions.

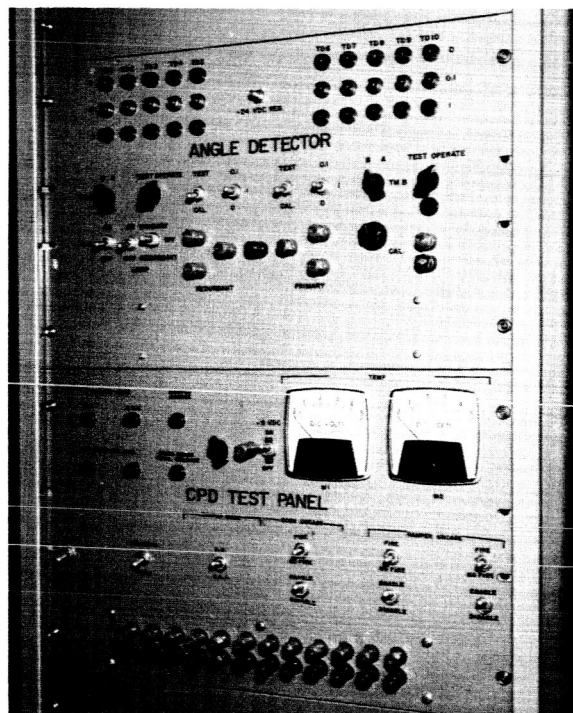


Figure 4-6. CPD Test Panels

SECTION 5

ATTITUDE SENSER SUBSYSTEM

5.1 TV CAMERA SUBSYSTEM

Testing of engineering model (serial No. 65102) was stopped due to a major breakdown of the carbon arc simulating the sun. The TV camera subsystem was removed from the vacuum chamber and returned to the vendor for rework. A list of specification deviations was prepared for formal transmittal to the vendor. Angular offset of the central reticle cross hairs to the alignment cross hairs was measured. A photographic record was made of the test chart as it appears in the TV presentation from the engineering model after the environmental testing. Interface drawings were revised to conform to latest drawings obtained from vendor and delivered to NASA/GSFC. It has been determined that, due to the displacement between the first nodal point of the TV field of view and the apex of the boom angle, the effective field of view in terms of boom angle is decreased.

Engineering testing was temporarily discontinued while reports of tests to date are prepared and deviations accrued so far are resolved. A report of the thermal-vacuum tests was written. A test to determine thermal lag from optice to vidicon faceplate was planned for engineering model (serial No. 5101). Data accumulated during corona tests of the engineering model were reorganized and presented to NASA/GSFC in terms of safe pressure outside the TVCS for avoiding internal corona discharge.

A reply by Lear-Siegler (LSI) to GE modifications of the Life Test Plan was reviewed with reliability engineering and requirements engineering. LSI is not yet complying with the requirements GE has placed and has indicated other changes to the life testing that we will not be concurring with.

PIR 4176-559 was issued defining the tolerances in maximum field of view and the probable maximum angle at which the boom ends will be observable. System input as to acceptable limits has been requested.

Analysis by thermal engineering is that the quartz window will be at highest temperature in the TV camera subsystem and that temperature will not exceed 200⁰ F. Substantiation of this will be obtained in TV tests already being planned. A PIR on report of TV tests to date was issued.

Discussions with the vendor were held at GE for three days. Updating of the source control drawings, component specification, life test is being implemented as a direct result. The vendor indicated that he assumes full responsibility to correct out-of-specification conditions of engineering model (serial No. 5102). It can be expected that the reticle will deteriorate before the rest of the retina when the vidicon faceplate is overheated. The 140⁰ F limit on the vidicon faceplate is to protect the reticle; the retina alone would enable operation to a high temperature.

Performance tests on the first engineering model (serial No. 5101) were made at high ambient ambient temperatures to study variations in the synchronizing pulses due to temperature. A phase displacement between vertical and horizontal pulse time bases occurs as a function of temperature. The temperature telemetry of the TV cameras does not conform to the calibration curve supplied by the vendor but the cause has not yet been determined. A new calibration curve is being generated experimentally using thermocouples mounted adjacent to the vendor-supplied thermistor. The temperature gradient between the vidicon faceplate and chassis-mounted thermistor is also being determined experimentally in the thermal vacuum chamber.

The vendor has supplied an updated, indented parts list of the TV camera subsystem which includes the latest drawing revision letters and change notices in accordance with agreements made during discussions with GE during the week of 15 November. LSI will supply an updated manufacturing flow plan, reticle orientation by vidicon serial number, and room temperature tolerances on a list of significant parameters of the TV camera subsystem, principally those contained in EIA Standard RS170, Revision TR135. The effect of each of these parameters on the boom target displacement measurement accuracy is presently being evaluated so that realistic and required tolerance may be compared with the limits LSI expects to meet.

5.2 SOLAR ASPECT SENSOR (SAS)

Engineering tests of the electronics unit at cold temperature continued. All data taken with the SAS in direct sunlight were reduced and printed out in tabular form. All readings were within specification. The engineering test plan is being revised to incorporate the changes recommended in PIR 4176-537. All schematics for the SAS tests rack have been brought up to date. The test rack has been completely rewired including the new transient generator.

A report on the engineering model tests is being prepared. The single engineering detector unit has been painted and will go into solar vacuum tests as soon as the facility becomes available. The remaining tests to be performed on the SAS system, magnetic dipole and transition edge check under carbon arc illumination, are also waiting for the facilities to become available. The other four engineering detector units have been assembled at Adcole and are undergoing final tests prior to shipment.

Data taken on delivered units were used to analyze the effect of changing the effective index of refraction in the transfer function. In most cases, the accuracy of the detectors at 25°C can be improved by changing the effective index of refraction, leaving a larger margin of operation at very low temperature.

5.3 POWER CONTROL UNIT (PCU)

The PCU breadboard model was used in preliminary system tests to further check out the AGE and interconnecting harnesses. The engineering model of the PCU was used to help verify the magnetic dipole test facility. The internal wiring list for the prototype and flight units was approved and released. The outline drawings for three units were compared with the HAC/GSFC interface drawing to ensure their agreement. The final test report on the engineering model was initiated.

Preliminary EMI tests on the engineering model PCU revealed a potential conducted susceptibility in the motor driver circuits. Further tests to determine the specific nature of the susceptibility resulted in the loss of the four field driver modules as a result of the faulty application of test equipment. New modules were built to replace those lost. The control stages of the motor driver circuits were changed to operate from the -24 volt regulated line in order to reduce the EMI susceptibility.

The EMI test was repeated on the engineering unit without the field driver modules, but it was not possible to reproduce the readings obtained in the first EMI tests performed in the RFI laboratory. The intermittent connections on the frame ground bus and on pin J13-15 inside the PCU engineering model, reported during early testing, were traced to a cold solder joint and to a pin partially coated with epoxy, respectively. With the exception of the replacement of the field driver modules, all testing on the PCU engineering model is complete, and the unit is ready for system testing. The PCU breadboard is continuing to be checked out with the AGE. The prototype model is still being constructed. Several parts problems have been encountered and are being resolved.

Three new field driver modules were pre-pot tested and found to be operating properly. A special cable was fabricated reversing the armature wires to the engineering model boom package, T-1a, so that the motor will operate in the correct direction. The PCU breadboard is being tested to determine if it will operate within some of the new units of the revised Interface Specification, S2-0401.

SECTION 6

GROUND TESTING

6.1 SYSTEM QUALIFICATION TEST PLAN

Modifications were made to the GE input for the HAC System Qualification Test Plan. These modifications were in compliance to a NASA request to define failures and recommend disposition of such failures. This document will be reissued during the week of 6 December.

6.2 AEROSPACE GROUND EQUIPMENT

Operating instructions for the AGE have been issued. This document includes a calibration procedure for each panel of the AGE Console.

The AGE has gone through the calibration lab and has received formal calibration status.

6.3 SYSTEM EVALUATION TESTING

Compatibility tests were successfully completed between the AGE and breadboard PCU. Formal system evaluation tests will begin after rework has been completed on the engineering unit of the PCU.

6.4 DIPOLE TESTING

In order to ensure a positive test technique for measuring the magnetic dipole of ATS components, a technical team was formed to develop a procedure for performing dipole checks in the GE facility including any precheckout functions. This effort was completed and the technique is described in PIR 4133-GKS-200.

6.5 COMPONENT QUALIFICATION TESTING

Revised qualification test cycles for each component were submitted to NASA for approval.

A TWX was received from NASA on 16 November 1965 approving the following cycles:

a. Combination Passive Damper

1. Electrical functional - ambient
2. Force functional - ambient and temperature ($T_{\max} + 15^{\circ}\text{C}$, $T_{\min} - 15^{\circ}\text{C}$)
3. Damping functional - ambient and temperature ($T_{\max} + 15^{\circ}\text{C}$, $T_{\min} - 15^{\circ}\text{C}$)
4. Humidity
5. Electrical functional - ambient
6. Vibration
7. Electrical functional - ambient
8. Acceleration
9. Electrical functional - ambient
10. Vacuum thermal ($T_{\max} + 10^{\circ}\text{C}$, $T_{\min} - 10^{\circ}\text{C}$, hot and cold soak)
11. Force functional - ambient
12. Damping functional - ambient
13. Electrical functional - ambient

b. Primary Boom

1. Functional - ambient
2. Leak
3. Humidity
4. Functional - ambient
5. Vibration
6. Functional - ambient
7. Acceleration
8. Functional - ambient

9. Vacuum thermal ($T_{\max} + 10^{\circ}\text{C}$, $T_{\min} - 10^{\circ}\text{C}$, hot and cold soak)
10. Leak
11. Functional - ambient

c. Damper Boom

1. Functional - ambient
2. Humidity
3. Vibration
4. Acceleration
5. Vacuum thermal ($T_{\max} + 10^{\circ}\text{C}$, $T_{\min} - 10^{\circ}\text{C}$, hot and cold soak)
6. Functional - ambient

Note

The pyrotechnic device must be fired in order to deploy. Functional tests between environments have been waived in order to permit the pyrotechnic device to be processed through the entire qualification cycle. An electrical check (no fire) will be performed on the pyrotechnic device between each environment.

d. TV Camera Subsystem

1. Functional - ambient
2. Humidity
3. Functional - ambient
4. Vibration
5. Functional - ambient
6. Acceleration
7. Functional - ambient
8. Vacuum thermal ($T_{\max} + 10^{\circ}\text{C}$, $T_{\min} - 10^{\circ}\text{C}$, hot and cold soak)
9. Functional - ambient

e. Solar Aspect Sensor

1. Functional - ambient
2. Humidity
3. Functional - ambient
4. Temperature ($T_{\max} + 15^{\circ}\text{C}$, $T_{\min} - 15^{\circ}\text{C}$)
5. Vibration
6. Functional - ambient
7. Acceleration
8. Functional - ambient
9. Vacuum thermal ($T_{\max} + 10^{\circ}\text{C}$, $T_{\min} - 10^{\circ}\text{C}$, hot and cold soak)
10. Functional - ambient

f. Power Control Unit

1. Functional - ambient
2. Humidity
3. Functional - ambient
4. Vibration
5. Functional - ambient
6. Acceleration
7. Functional - ambient
8. Vacuum thermal - ($T_{\max} + 10^{\circ}\text{C}$, $T_{\min} - 10^{\circ}\text{C}$, hot and cold soak)
9. Functional - ambient

SECTION 7
MANUFACTURING

The status of manufacturing to the end of November is listed as follows:

- a. Engineering Unit 1 - The unit was completed and delivered for Engineering test.
- b. Engineering Unit 2 - All mechanical parts are complete. The electronic parts are about 80% complete. The final assembly is scheduled to start during the week 6 December 1965.
- c. Prototype Units 1 and 2 - Manufacturing of these units is about 75% complete.
- d. Flight Units - Manufacturing has been started on the mechanical portion. All ordering is complete.
- e. Ground Support and Test Equipment - Manufacture of the last set of ground support equipment is about 70% complete. Test equipment is about 90% complete.
- f. Tooling - All major tooling is complete.

SECTION 8

QUALITY CONTROL

8.1 GENERAL

The Gravity Gradient System Qualification Test Plan was completed and copies forwarded to NASA.

Several meetings were held concerning the Magnetic Test Facility. Tests were run on the PCU and a tentative method for dipole testing was issued in PIR 4133-GKS-200. The dipole testing will be performed by QC and Test technicians to determine the magnitude and orientation of the dipole of each component both operating and nonoperating. This information will be turned over to Engineering for review but will not form a basis for acceptance or rejection of the component.

8.2 BOOM SUBSYSTEM

Authorization for material review action was forwarded to deHavilland during the reporting period. The Material Review Board will consist of a GE member, Canadian Air Force member, and two deHavilland members representing Engineering and Quality Control.

Vendor surveillance activity at deHavilland consisted of in-process inspections on the engineering units during the period.

8.3 COMBINATION PASSIVE DAMPER

A program for producing acceptable electron beam welding, including the preparation and evaluation of samples, certification of equipment, operator certification and inspection methods, is underway and shall be complete prior to fabrication of the prototype weldment (47D207306).

Problems encountered in the manufacture of the angle indicator calibration fixture 47R205601 by Ludwig Honold Mfg. Co. continue. The item was rejected at the vendor, some corrections were made and upon receipt at GE additional discrepancies were discovered. A corrective action report was prepared asking for documented vendor QC explanation and action.

Quality Control personnel witnessed the assembly of the Engineering Unit 1 CPD and participated with many of the adjustments. In addition QC and Test technicians are performing the engineering evaluation testing under Engineering direction.

The CPD alignment fixture fabrication is in a "holding status" pending resolution of the NASA/HAC/GE interface.

The angle indicator encoder disc (GE Dwg 47C207272) actual size master was inspected at GE. Results of the inspection were discussed with the vendor (Chem-Fab Corp), and a new master will be fabricated.

8.4 TV CAMERA SUBSYSTEM

Discussions were held with the Lear-Siegler Quality Control representatives and their Contract Manager. Results of the meeting include updating the source control drawings, component specification, vendor drawings, and test plan. As a result of revising the component specification, it is anticipated that additional testing, test equipment and fixturing will be required. Effort was begun to identify these requirements.

8.5 SOLAR ASPECT SENSOR

Adcole Corporation was visited by the vendor surveillance on two occasions to inspect the printed circuit boards and solar cell assembly, and review over-all status. Adcole's efforts to resolve a process control problem at the solar cell vendor (Hoffman Electronics) are commendable. Adcole's Quality Control Manager played an important role in resolving

the problem of soldering the platinum tabs to the solar cells. As a result, Hoffman reported success on five units from the regular production run. The one assembly at Adcole was accepted for soldering to NPC 200-4 and the printed circuit boards were also accepted.

The electronics test equipment is being put into acceptable shape for the quality control testing which will start on the prototype units. All schematics were updated and layout drawings are close to completion. The rewiring required is essentially complete.

Uniformity of the sun source is still a problem. Additional evaluation disclosed that the existing bulb does not have good optical properties. A review of the test plots of other bulbs show better optical properties and a new bulb is evaluated.

8.6 POWER CONTROL UNIT

Many of the prototype piece parts have been processed through the Parts Test Laboratory.

In order to facilitate an orientation inspection of module fabrications, a cross reference type drawing (GE Dwg 490L116) was created from the HAC and GE specifications which lists the vendor part number and GE specification.

Design and fabrication of PCU test equipment is progressing. Most of the module test boxes have been fabricated. The card test boxes are presently in design.

Preliminary EMI tests of the engineering unit revealed a potential conducted susceptibility. Magnetic dipole investigations were completed on the same unit.

SECTION 9

RELIABILITY AND PARTS AND STANDARDS

9.1 RELIABILITY

A response to NASA's commentary on the Reliability Program Plan has been prepared. Most of NASA's suggestions have been incorporated into the plan. A list of proposed exceptions has been submitted to GE-SD Program Management for internal review.

A failure mode/effects analysis is currently in progress on the CPD. This effort, when completed, will include the eddy-current damper clutch mechanism, caging mechanism, and angle indicator assembly. Data from TRW's analysis of the passive hysteresis damper will be incorporated into an overall CPD reliability assessment.

A risk assessment of the boom system experiments is also in progress, integrating the results of deHavilland's analysis of the boom system itself with in-house analyses of associated components.

9.2 PARTS & STANDARDS

9.2.1 COMPUTER PROGRAM

The degradation analysis of parts is continuing at a high level of effort. About 70% of the extended power aging data on parts used by Adcole in the solar aspect sensor have been received and processed. Upon completion of degradation analysis on each lot, the subcontractor is advised of the acceptable parts listed in order of preference. Problems arising from anomalies in the test data are found in essentially every lot of data. Some of the typical problems are:

- a. Errors in punching data onto cards
- b. Wrong number of cards, i.e., more cards or less cards than the number of parts in the lot

- c. No data on cards, i.e., blank cards
- d. Incorrect location of decimal point
- e. Data missing for a particular time period
- f. Cards stacked out of order.

Each problem was resolved as it arose and the data processing continued.

9.2.2 PARTS QUALIFICATION PROGRAM

The final report of the qualification testing of the Horex Cable Cutter was issued in PIR 4182-15, dated 20 October 1965.

Two items have been added to Group A of the Parts Qualification Program. These are the linear actuator assembly supplied by Horex and the ball-lock release assembly supplied by Avdel. These items are presently being procured for test.

ETP-4165-1, issued 11 November 1965, is an Engineering Test Plan for accelerated testing of miniature lamps. It specifies an operational accelerated life test on a total of 75 lamps. The purchase order for the materials and the testing has been placed with Chicago Miniature Lamp Works.

9.2.3 PARTS EFFORT

Interface with subcontractors to resolve parts problems continued. Some of the areas covered were discussions of parts characteristics, selection of parts specifications, and procurement problems. Similar problems but in increasing numbers are encountered internally. Some of the problems handled inside GE are: wrong parts delivered by the vendor, the order specified the wrong parts, and parts delivered were incorrectly marked.

Such problems demand a continuous and concentrated liaison until they are resolved.

9.2.4 PARTS DRAWINGS AND PARTS LISTS

A part number cross reference list for ATS (GE Drawing 490L116) was prepared and issued. This document was necessary because the HAC parts, in general, lose their identity as HAC or GE parts when they are removed from their containers. They are marked with a vendor's designation. The cross reference list correlates the vendor's part number with the GE part number for each part used.

A list of parts used by Lear-Siegler in the TV camera subsystem was issued. This list is required documentation in conformance with Specification No. SVS-7338. It will be revised to reflect changes as they are made known.

The following GE drawings were revised and updated during the reporting period:

R4508, Rev. B	R4528, Rev. A
R4510, Rev. A	R4535, Rev. A
R4513, Rev. B	R4536, Rev. A
R4515, Rev. B	R4540, Rev. A
R4518, Rev. C	R4611, Rev. A
R4521, Rev. B	R4612, Rev. B
R4526, Rev. A	

In addition, the HAC drawings referenced in the above listed GE drawings were updated.

SECTION 10
SPECIFICATION STATUS

The following lists the number and title for each component specification associated with the ATS Gravity Gradient Stabilization System. The Space Vehicle Specification (SVS) number designates the particular document which is recorded and controlled within the GE Spacecraft Department.

<u>Specification No.</u>	<u>Title</u>	<u>Status</u>
SVS-7306	Solar Aspect Sensor-ATS	Revision B - 1/4/65
SVS-7307	Power Control Unit-ATS	Review (Awaiting Comments)
SVS-7310	TV Camera Subsystem-ATS	Revision D - 7/16/65
SVS-7314	Combination Passive Damper	6/4/65
SVS-7316	Boom Subsystem	Revision C - 4/28/65
SVS-7325	Standard Parts, Materials and Processes, Use of	Revision C - 1/4/65
SVS-7331	Passive Hysteresis Damper	3/8/65
SVS-7338	Standards, Engineering Equipments	Revision B - 4/15/65

SECTION 11

PROGRAM SCHEDULE

The schedule for the hardware items which will be delivered for use by the spacecraft contractor is shown in Table 11-1. The schedule is a summary of the detailed PERT networks which have been established and will be maintained for program control. The schedule is based on the revised program defined in the Work Statement, GE Document 65SD4293 dated 20 April 1965.

**TABLE 11-1. DELIVERY SCHEDULE FOR GRAVITY
GRADIENT STABILIZATION SYSTEMS**

	1965												1966											
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Thermal Model									▲															
Dynamic Model									▲															
Prototype Unit																△								
Flight Unit No. 1 (ATS-A)																					△			
Flight Unit No. 2 (ATS-D)																					△	*		
Flight Unit No. 3 (ATS-E)																						△	**	

△ Estimated Delivery Date

▲ Actual Delivery

* To Be Retained By G. E. Unit Sept. 1, 1967

** To Be Retained By G. E. Until Mar. 1, 1968

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